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Eurasian Coots are one of our most familiar waterbirds commonly seen on both small and large urban wetlands.

Photo: Lake Monger, Warren Dell.

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General Meetings and Branch Meetings are held at various venues in Nedlands, Kalamunda, Rockingham and North Beach.
The Retired and Leisured Group meets on alternate Wednesdays at 10a.m.
Excursions and field days are planned from time to time and will be advertised in the Club's monthly newsletter "The Naturalist News".

THE WESTERN AUSTRALIAN NATURALIST

(Journal of the W.A. Naturalists' Club)

Editor

MR JOHN DELL

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THE WESTERN AUSTRALIAN

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Vol. 31 25th November 2017 No. 1

THE FIRST NESTING OBSERVATIONS OF A POTTER WASP *RHYNCHIUM SUPERBUM* (VESPIDAE, EUMENIDAE) – A RECENT EASTERN INVADER INHABITING THE SUBURBS OF PERTH WESTERN AUSTRALIA

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Rhynchium superbum Saussure, 1852 is an attractive potter wasp (family Vespidae, subfamily Eumenidae) native to the eastern states of Australia (Photo 1, Photo 3). In recent years observations of this wasp have been reported from Western Australia (Houston, 2016). The first record of a specimen to the WA Museum was from a suburban garden in the south-eastern suburb of Kelmscott, in 2010. Reports, accompanied by photos, followed, from Waikiki (south of Rockingham) in 2014, and from Swan View (on the Darling Escarpment) in 2015 (Houston, 2016). The next observation was reported by me, where in 2016 I photographed an individual resting on the wall above a door in the suburb of Wembley at around 10pm. Although Perth has a number of native potter wasps, none are in the genus *Rhynchium*, nor are any so large, or, it can be argued, so "superb" (hence the species epithet). Following this observation of a large, beautiful wasp, I reported it to Dr Terry Houston, expert in hymenopteran taxonomy and ex-curator of entomology at the WA Museum. Terry was very interested, and informed me I'd found a *Rhynchium superbum*. He kindly provided me with 10 pine batons with approx. 10mm diameter holes drilled in them to place around the garden of the Wembley property to encourage a female *R. superbum* to nest in them, and thus obtain specimens. In particular, the WA Museum lacked a male specimen.

Unfortunately, none of the batons became occupied.

The following year in 2017 however yielded many *R. superbum* specimens, but inadvertently! The Wembley property was selected as one of 14 sites I surveyed over the spring/summer period for my PhD: "Determinants of native bee assemblages in urban habitat fragments in the southwest Australian biodiversity hotspot and interactions between honeybees (*Apis mellifera*) and native plant-pollinator communities." From October, eight "bee hotels" (also known as trap-nests) made out of blocks of Jarrah (*Eucalyptus marginata*) of dimensions 200mm x 100mm x 100mm were installed in tree branches or under eaves at 14 sites (7 residential, 7 bushland) across the Perth metropolitan and suburban region. Inserted into holes drilled in each block were 15 cardboard bee tubes, 12cm long, five each of 4mm, 7mm and 10mm in diameter. During monthly surveys at each of my sites, completed tubes (evidenced by being capped with materials characteristic for a given bee taxon) were removed and placed in individual perforated plastic take-away containers in the lab to develop at room temperature, and replaced with new tubes into the trap-nests.

At Wembley, whilst undertaking my survey in January I spied a *Rhynchium superbum* resting on the succulent *Portulacaria afra* (Photo 1). Furthermore, I saw it then fly up and enter a 10mm diameter cavity in one of my bee hotels. As indicated by the com-

Photo 1. Female *Rhynchium superbum*, photographed in a residential yard in Wembley, WA, in December 2016, where nesting activity at bee hotels occurred.

mon name for its subfamily – potter wasps – it was collecting mud to seal up the nesting tube. Through the partly closed entrance could be observed lepidoptera larvae, stocked to provide food for the offspring when they hatched (Photo 2). On one of her visits to the tube, I collected the female so I could provide Terry with a specimen. I contacted Terry and, with some effort, given the tight fit between the outer cardboard bee tube with the inner surface of the wooden hole, the tube was extracted and the offspring it contained were reared in the lab at the WA Museum. A lucky coincidence was that all four of the wasps that emerged were the rarely collected males.

The following month during the survey conducted on 18 February, five more 10mm tubes were collected containing *R. superbum*. Prior to collection, over a number of days a female was observed attending to the bee tubes it was using as a nest and plastering the surface with mud to seal the contents. The collected tubes were left in the lab to develop in an perforated plastic take-away container. On 5 March, four wasps emerged, with another three emerging on 7 March, four more on 17 March, and then two more wasps emerged on 19 March. In total,

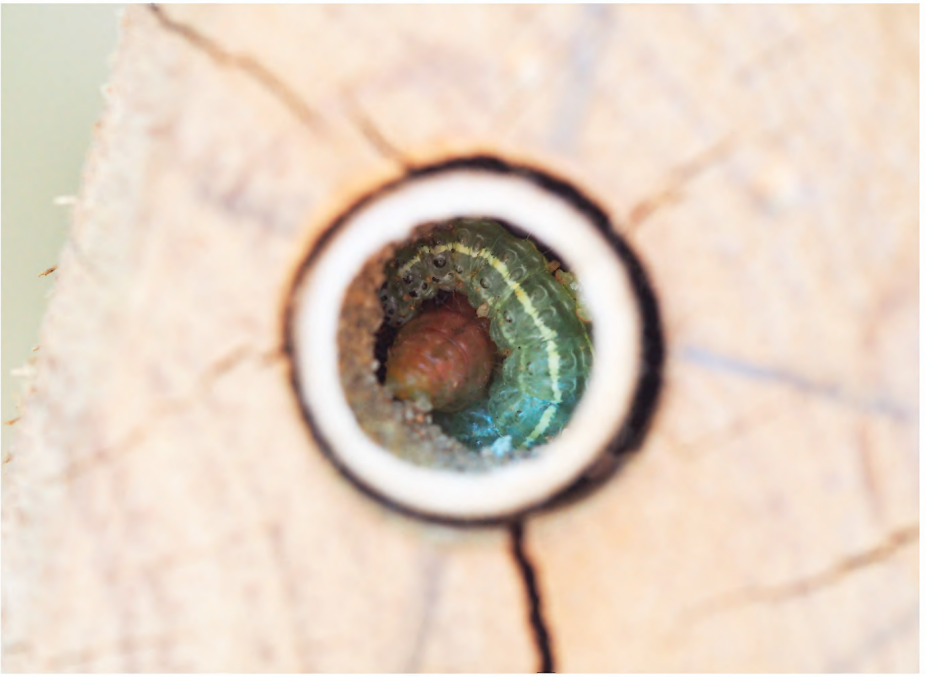

Photo 2. 10mm bee hotel cavity utilised by *Rhynchium superbum* with lepidopteran larva prey.

out of the five tubes, 13 wasps emerged: four females, and nine males (Photo 3, Photo 4). Whether this male-biased sex-ratio is typical for the species is unknown, but it may be that the lack of a larger diameter than the 10mm tubes restricted the number of female offspring, given that diameter size has been found to limit female offspring production in another *Rhynchium* species (with males being the smaller-bodied sex in *Rhynchium*, including *R. superbum*) (Budriene, 2004).

Photo 3. *Rhynchium superbum* male (left) and female (right), emerged from bee tubes.

Photo 4. *Rhynchium superbum* that emerged from bee tubes collected from bee hotels installed in Wembley, WA.

It is ironic that *R. superbum* failed to utilise the trap-nest batons set out for it, and then usurped some of the bee tubes I had put up for my bees. With the exception of utilising the bee tubes, *R. superbum* did not appear to deter native bees from nesting, as numerous megachilids utilised bee tubes in the same bee hotels occupied by *R. superbum*. Indeed, across my studies, few bees nested in the largest diameter bee tubes (10mm) and out of all of the bee hotels at the Wembley site, only three out of the forty 10mm tubes present were occupied by bees over the entire duration of the study.

In the report by Houston (2016) on *R. superbum* in WA, it was noted that nesting habits of *R. superbum* had never been described, and whether *R. superbum* used pre-existing hollows, or constructed their mud nests in exposed situations, was unknown. No records for the nesting habits of any of the other six *Rhynchium* species in Australia likewise have been published, however *Rhynchium* species in other countries had been recorded in bee hotels (trap-nests) e.g. (Bos *et al.*, 2007; Höhn, 2007). My observations therefore establish that this Australian *Rhynchium* species will likewise occupy trap-nests, and that trap-nests with holes 10mm diameter can be used to monitor this species (Frankie *et al.*, 2002).

Given that most *R. superbum* in WA have been recorded from suburban areas suggests that this species responds favourably to urbanisation. Studies of other *Rhynchium* overseas likewise suggest that species in this genus are tolerant to, or even benefit from, anthropogenically-modified habitats (Bos *et al.*, 2007; Höhn, 2007).

The effect of this eastern Australian species on WA's native fauna is unknown. There is the potential for *R. superbum* to have adverse effects on native wasps or larger cavity-nesting bees and wasps through competition for food and resources, respectively. *R. superbum* may also detriment native lepidoptera populations via predation on their larvae. However, *R. superbum* may provide important and free pest control of phytophagous lepidoptera larvae; indeed, other species in the genus are considered to be important predators of pests in agroforestry (Höhn, 2007). Therefore, the establishment of *R. superbum* may be considered beneficial in habitats like residential gardens such as the one I collected it in where its predatory activities may reduce the damage from caterpillars on garden flora.

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A LIMESTONE SUBSPECIES OF *PETROPHILE BREVIFOLIA* LINDL. (PROTEACEAE)

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ABSTRACT

A distinctive pink flowered form of *Petrophile brevifolia* observed during the Swan Coastal Plain Survey occurring on Tamala limestone near the coast north of Lancelin is described as a new subspecies, *Petrophile brevifolia* subspecies *rosea*.

INTRODUCTION

During surveys for a floristic analysis of the Swan Coastal Plain and the conservation status of its component species (Gibson *et al.* 1994 and Keighery 1999) a pink flowering form of *Petrophile brevifolia* was recorded on shallow limestone soils at the northern margin of the study area. Subsequent collecting has revealed that all plants on limestone in the northern section of the Swan Coastal Plain bioregion are pink flowered.

In his revision of *Petrophile* in the Flora of Australia, Foreman (1995) noted that *Petrophile brevifolia* has flowers that are yellow or cream to white and that when infused in hot water they give off a brilliant yellow colour. He does not mention that any plants are pink flowered. Rarely are there such dramatic colour differences within a species of *Petrophile*. Previously this was only known in *P. serruriae* where the limestone coastal variant with pink flowers is now known as *P. axillaris* Meisn.

This distinctive pink flowered form may have been the source of confusion noted in distinguishing *Petrophile media*, *P. linearis* and *P. brevifolia* in the Flora of the Perth Region (Marchant *et al.* 1987).

Lindley (1840) in his description of *Petrophile brevifolia* cited no type, however, in his description of the species he notes (page xxxv) "Another species, *P. brevifolia*, has flowers which, if infused in hot water, give out so brilliant a yellow colour that it is worth examination as a probable source of dyeing material."

Figure 1. Pink Flowered *Petrophile brevifolia* subspecies *rosea* from Type Population.

Obviously the material Lindley examined was the yellow flowered form.

The pink flowered variant is confined to limestone soils and no overlapping populations are known. The variant deserves recognition and fits the concept of a subspecies, in being a morphological variant occupying a distinct habitat and geographical range.

TAXONOMY

Petrophile brevifolia subspecies ***rosea*** Keighery & Keighery

Differs from *Petrophile brevifolia* in having pink flowers with grey hairs rather than yellow flowers with white hairs.

Typus: 11 Km. east of Cervantes, 21-Oct.-1990, G.J. Keighery 11872 (Holo: PERTH 02473925, iso: MEL).

Description of the subspecies: A multi-stemmed erect shrub to 30 cm. tall by 30 cm. wide. Branchlets and leaves are glabrous. Leaves are simple, terete, straight, 10 –23 cm long terminating in a pungent point. Inflorescence depressed-globose in shape, terminal on branchlets, sessile, 35–40 mm diameter. Involucral bracts of the inflorescence, numerous, erect or curled at apex, linear-subulate. Inflorescence cone scales ovate, acuminate, imbricate, glabrous. Flowers 20–28 per head, pink with grey hairs, 15–20 mm long. Pollen presenter c. 4 mm long, broadly turbinate, truncate below the brush, glabrous, brush 2–3 mm long, narrowly cylindrical, short and spreading, hirsute with a glabrous tip. Cones globose to ovoid, 10–20 mm long. Nuts c. 3 mm long.

Other Collections examined. (All PERTH). Near Mt. Lesueur National Park, S. of Green Head, 3-Sept.-1985, E.A. Griffin 4204; Eneabba Flora Reserve, 12-Sept.-1966, A. Kessell s.n.; Yandanogo Nature Reserve, 13-Oct.-1989, E.A. Griffin 5557; 500 metres on Sappers road to Korallin road, east of Lancelin, 20-Sept.-1966, E.A. Scrymgeour 1342B; 300 metres north of Jurien Bay road on Sappers road, 6.4 km. E. of Jurien Bay, 9-Oct.-1995, N. Hoyle 778; 5 km. SE of Jurien Bay, 15-Oct.-1988, G.J. Keighery 10364; Sappers Road, 11 km. SE of Lancelin, 22-Oct.-1990, G.J. Keighery 11954.

Distribution and Habitat: This subspecies of *Petrophile* is confined to Tamala limestone soils of the western side of the Swan Coastal Plain between Lancelin and Dongara. Usually growing in *Banksia sessilis* shrubland or low mixed heath. Re-sprouts from a lignotuber after fires.

Conservation code. Widespread and well reserved (Keighery 1999). Present in Beekeepers Nature Reserve, Proposed extensions to Mount Lesueur National Park, Nilgen Nature Reserve and Nambung National Park.

Notes: This distinctive pink flowered subspecies is confined to Tamala limestones on the western margin of the Swan Coastal Plain.

DISCUSSION

Pink flowering *Petrophile brevifolia* occupies and is confined to the coastal Tamala limestone from Lancelin to north of Coolimba on the Swan Coastal Plain. There is a rapid changeover south of Lancelin to yellow flowered populations on the same geology, e.g.: recorded

from Ledge Point R. Pullen 9782 (PERTH) and Ningana Block B.J. Keighery 817B (PERTH). Currently there are no known populations that where the two forms co-occur, nor are any intergrading populations known.

The pink flowered form occupies a distinct geographic and ecological range from the nominate sub-species and well fits recognition in a sub-specific category.

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AVIFAUNA OF UNDERWOOD AVENUE BUSHLAND, SHENTON PARK, WESTERN AUSTRALIA

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ABSTRACT

Underwood Avenue Bushland (UAB) is, at 31.5 ha, the third largest remnant of native vegetation remaining in the western suburbs of Perth (after Bold Park, 361.7 ha and Kings Park, 320.8 ha). During the period 2002–17 we recorded 59 bird species, 12 of which are resident or of regular occurrence. Another 11 species occur as regular/seasonal visitors. Most species (32) are either vagrant or irregular visitors. The remaining four species are of uncertain status. Based on nesting observations and current status, at least 20 species use the bushland for breeding.

UAB provides important resources for several iconic bird species: the threatened Carnaby's Cockatoo, listed as Endangered by the Commonwealth of Australia under the Environment Protection and Biodiversity Conservation Act (food plants); and the Forest Red-tailed Black Cockatoo, listed as Vulnerable (food plants). Both cockatoo species are listed as 'Rare or likely to become extinct' under Western Australian legislation. There is also the apex predator Brown Goshawk (nest sites). UAB provides resources for at least 13 other bird species that are recognised by government as regionally significant on the Swan Coastal Plain because of major declines in population or distribution. Also occurring are Rainbow Bee-eater, Striated Pardalote, Western Gerygone, and Rufous Whistler, species regarded by Moore and Barrett as declining in the Perth metropolitan region.

Under threat of partial clearance for housing, UAB should instead be preserved as a significant stepping stone between bushland in Bold Park, Shenton Bushland, and Kings Park, and be actively managed by vigilant control of Perennial Veldt Grass, foxes, and feral cats, and prevention of wildfire.

INTRODUCTION

Urbanisation since 1829 has diminished the extent of bushland on the Swan Coastal Plain. In the suburbs west of Perth, little remains apart from Kings Park and Bold Park (Keighery and Keighery 2015). At 31.5 ha, Underwood Avenue Bushland (UAB) is the third largest

remnant of native vegetation in the western suburbs. Despite being listed as Bush Forever Site No. 119 (Government of Western Australia 2000), the future integrity of this remnant, owned by the University of Western Australia (UWA), is not secure. Since 1998 the university has been actively seeking to procure approval to clear most of the bushland for the purpose of building c. 300 residential units (Prince 2002, EPA 2003). This is to generate revenue for teaching and research. The authority for doing so is based on legislation by the Parliament of Western Australia (University Endowment Act 1904). UAB was included within more than 1600 ha of mostly suburban lands that were set aside as an endowment for a future university (Ferguson 1993).

UAB became isolated from Bold Park during the 1950s (Seddon 1972: 194, Jarvis 1979: 52). Nevertheless, its potential value as a stepping stone for bird species between remnant vegetation at Kings Park, Bold Park, Shenton Bushland, and Herdsman Lake is illustrated in the maps published by the Perth Biodiversity Project (2013).

The list of bird species recorded in the early 1980s on the 'campus' of UWA by Ambrose and Serventy (undated) was based on the main campus at Crawley and did not extend to the Shenton Park campus, i.e. the area which includes UAB. Nor did the study of birds in remnant bushland in the Perth metropolitan region include UAB in its 42 sites (Majors 1988). The avifauna of UAB was thus undocumented until the study undertaken nearly 20 years ago (from 1998 to 2001) by Berry and Berry (2008). In this paper we present information collected from 2002 until the present.

The vegetation of UAB comprises Banksia woodland dominated by eucalypt trees (Fig. 1). Jarrah *E. marginata* (12–22 m) and Tuart *Eucalyptus gomphocephala* (12–30 m in height) are the main tree species. Marri *Corymbia calophylla* (30 m) has a more limited occurrence and Redheart *E. decipiens* (15 m) grows only on the western side of the bushland. Acorn Banksia *Banksia prionotes* (6–9 m, Fig. 1), Firewood Banksia *B. menziesii* (7 m), and Slender Banksia *B. attenuata* (10 m) are the main banksia species. Botanical names mostly follow Barrett and Tay (2016). Also present are two *Dryandra* species. Prominent members of the lower understorey (up to 5 m) include Grey Stinkwood *Jacksonia furcellata*, Stinkwood *J. sternbergiana*, Sandplain Zamia *Macrozamia fraseri*, and Balga *Xanthorrhoea preissii*. The ground flora (up to 1 m) is largely intact in about half of the woodland and comprises >150 native species and nearly 60 exotic species. The remainder is dominated by the introduced Perennial Veldt Grass *Ehrharta calycina*. The ground flora of part of the south-west portion of UAB is dominated by Narrow Leaf Lupin *Lupinus*

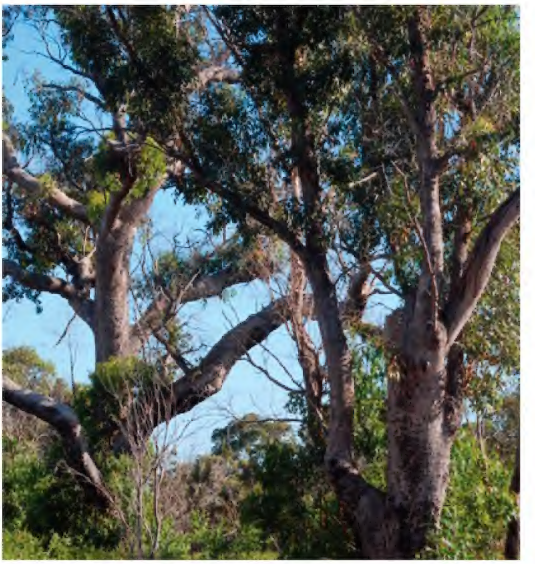

Figure 1. Some important habitat tree species. Top left: Tuart woodland. Top right: Jarrah woodland. Lower left: *Banksia prionotes* woodland, with Carnaby's Cockatoo. Right: Marri trees present in Jarrah woodland.

angustfolius and Fountain Grass *Cenchrus setaceus*.

UAB is surrounded to the east by housing along Selby Street, to the north by housing and business premises along Underwood Avenue, to the west by agricultural land, business premises, and playing ovals along Brockway Road, and to the south by business premises, charity organisations, a housing development, and the Subiaco Waste Water Treatment Plant. There is no road along the southern boundary of UAB. The UWA-owned land situated immediately west of UAB was developed in the late 1950s/early 1960s for agricultural experiments involving plant breeding (R. Boyd, J. Gladstones, D. Lindsay, A. Robson pers. comm.). Animal yards were used for zoological studies in the 1960s (D. Bradshaw pers. comm.). As a sure indication of its increasing use, the 'Experimental Station Shenton Park' was first listed in the telephone directory in 1960.

METHODS

One of us (MO) became particularly interested in UAB following a large wildfire in January 2002. This started in a skip bin just outside the southern boundary. She began writing a natural history diary about the post-fire recovery of the bushland and photographing species of interest. Gradually she contributed items of interest to a local, widely-circulating weekly newspaper (*Post*, Subiaco) and came to focus on cockatoos. The list of bird species recorded was, however, not always comprehensive and often omitted conspicuous species common in suburbia. In order to partially compensate for this, we have followed Berry and Berry (2008) in grouping MO's records into four-year periods. Her visits during the 16 years from 2002 to 2017 exceed 1000.

In 2013 IA contacted MO, who introduced him to UAB. On 11 visits (see Table 1 for dates), all bird species seen or heard by him (often accompanied by MO) in the bushland or immediately adjacent to it during 1.5–2 h (starting c. 0800 h) were recorded.

In our analyses, we divide the bird species recorded into two major categories:

- Current status in UAB, comprising the four subcategories of Resident/Regular occurrence; Regular/Seasonal visitor; Vagrant/Irregular Visitor; and Uncertain status; and
- Species, comprising the four subcategories of All species; All landbird species; All original species (i.e. those that occurred in the Perth region when Perth was first settled by Europeans – thus excluding Australian White Ibis, Laughing Kookaburra, Galah, Little Corella and Rainbow Lorikeet); and All original landbird species (a subset of the previous category).

Significant dates are cited in the text as month/year. The day is included only if important.

RESULTS

We recorded 59 species (Table 1), the most notable of which are the Brown Goshawk, Forest Red-tailed Black Cockatoo, Carnaby's Cockatoo, Variegated Fairy-wren, Western Spinebill, Yellow-rumped Thornbill, and Rufous Whistler (Fig. 2, Fig. 3). The status of all species recorded from 2002 to 2017 is discussed below. The first 10 visits made in the period 2013–17 indicate that the accumulation of species began to level off after the 7th visit (Fig. 4). This was confirmed on our 11th visit. The trends for All landbird species and All original landbird species hint at some levelling off by the 9th visit. We consider it most unlikely that any residential species and regular visitors present during our period of study remain overlooked.

Of the bird species recorded, 12 species are regarded as resident or of regular occurrence, and 11 species are considered to be regular or seasonal visitors. Most species (32) are vagrant or irregular visitors.

Resident/regular occurrence

In the sections below, 'recorded in all months' refers to the period 2002–17 and does not necessarily signify that such species occurred in every month during this period.

Brown Goshawk (Fig. 2). Recorded in all months, most frequently from June to February. Usually 2 adults present. First identified definitively in 7/02, when a dead bird was found. P. Berry confirmed its identity. Nesting observed 1/04, 11/04, 12/05, 1/16, with one juvenile the usual result. MO was swooped in 12/14, 9/15, 7/16, 8/16, 11/16, 12/16, 7/17. Observed being chased by Little Corellas, Western Ravens, and Willie Wagtails.

Rainbow Lorikeet. Recorded in all months. Nests in hollows. Observed harassing an Australian Hobby.

Brown Honeyeater. Recorded most commonly in June–December. Nest found with 2 young in 12/11 just south of UAB in *X. preissii*.

Red Wattlebird. Recorded in all months. Young being fed in 11/04.

Striated Pardalote (Fig. 3). Recorded in all months. Seen entering hollows 7/10, 1/16, and 9/17.

Weebill. Recorded in all months. Nest found in Jarrah foliage 11–12/09.

Western Gerygone (Fig. 3). Recorded in all months. Young seen on ground being attended by adult 12/03; young with adult 12/06.

Yellow-rumped Thornbill (Fig. 3). Recorded in all months. Nest-building 7/04, 9/06 (nesting), 11/14 (nesting).

Grey Butcherbird. Recorded in all months, except February.

Table 1. Bird species recorded on numerous visits by Berry & Berry 1998–2001 and Margaret Owen (2002–17), and on 11 visits (2013–17) by Ian Abbott (often with MO) to Underwood Avenue Bushland. Symbols: √ = recorded within the bushland; + = heard or seen from within the bushland but outside; ? = species identification uncertain; * nesting recorded. Species nomenclature follows Johnstone & Darnell (2015), except for more recent information.
Species listed as 'Significant birds of the Swan Coastal Plain portion of the Perth Metropolitan region' in Government of Western Australia (2000: 61–63) are highlighted in light grey. Species listed as 'Small insectivorous birds thought to be declining in the Perth region' by Moore & Barrett (in press) are highlighted in dark grey.

Species	1998–2001	2002–2005	2006–2009	2010–2013	2014–2017	14.6.2013	1.9.2013	29.10.2013	1.4.2014	15.8.2014	14.11.2014	27.3.2015	2.9.2015	2.9.2016	31.1.2017	29.9.2017
Australian Shelduck *Tadorna tadornoides*	√	√	√	√	√+	√							√			
Australian Wood Duck *Chenonetta jubata*				√	√	√				√+				√		
Pacific Black Duck *Anas superciliosa*							√									
Australian White Ibis *Threskiornis moluccus*					√	√	√	+	+	√	√	+	√	√		√
Straw-necked Ibis *T. spinicollis*					√+				+							
White-faced Heron *Ardea novaehollandiae*					√										√	
Black-shouldered Kite *Elanus caeruleus*	√		√		√+											
Little Eagle *Hieraaetus morphnoides*	√*	√	√	√	√											
Brown Goshawk *Accipiter fasciatus*	√*	√*		√	√*		√		√				√+	√	√	√

Species	1998–2001	2002–2005	2006–2009	2010–2013	2014–2017	14.6.2013	1.9.2013	29.10.2013	1.4.2014	15.8.2014	14.11.2014	27.3.2015	2.9.2015	2.9.2016	31.1.2017	29.9.2017
Collared Sparrowhawk *Accipiter cirrocephalus*	√	√*	√*	√												
Painted Button-quail *Turnix varius*	√	√	√		√											
Domestic Pigeon *Columbia livia*									+	+	√	√				
Spotted Turtle-Dove *Streptopelia chinensis*	√*				√	+	+	√	√	√	√				√	√
Laughing Turtle-Dove *S. senegalensis*	√*				√											√
Common Bronzewing *Phaps chalcoptera*					√											
Shining Bronze Cuckoo *Chrysococcyx lucidus*					√											
Pallid Cuckoo *Cacomantis pallidus*	√	√			√											
Barn Owl *Tyto alba*					√											
Boobook Owl *Ninox boobook*				√												
Tawny Frogmouth *Podargus strigoides*	√	√		√	+											
Laughing Kookaburra *Dacelo novaeguineae*	√		√	√*	√*	√		√	√		√	√+	√	+	√+	√

Species	1998–2001	2002–2005	2006–2009	2010–2013	2014–2017	14.6.2013	1.9.2013	29.10.2013	1.4.2014	15.8.2014	14.11.2014	27.3.2015	2.9.2015	2.9.2016	31.1.2017	29.9.2017
Sacred Kingfisher *Todiramphus sanctus*	√	√			√											
Rainbow Bee-eater *Merops ornatus*	√	√*	√*	√*+	√*			+			√+				√	
Australian Kestrel *Falco cenchroides*					√+					+	+		+	+		
Australian Hobby *F. longipennis*	√	√	√	√	√+											
Peregrine Falcon *F. peregrinus*					√											
Red-tailed Black Cockatoo *Calyptorhynchus banksia*			√√	√	√		√	√	√	√	√	√	√	√	√	√
Carnaby's Cockatoo *C. lateralis*	√	√	√	√	√		√			+	+	+	√		+	
Galah *Cacatua roseicapilla*	√*	√	√	√	√	√				√+	√	+	√+	√	√	+
Little Corella *C. sanguinea*	?√*	√	√	√	√	√	√	√	+	√	√	+	√	√	√	√
Rainbow Lorikeet *Trichoglossus moluccanus*	√*		√		√	√	√	√	√	√	√	√	√	√	√	√
Australian Ringneck *Platycercus zonarius*	√*	√			√											√
Variegated Fairy-wren *Malurus lamberti*		√	+	√	√							√				

Species	1998–2001	2002–2005	2006–2009	2010–2013	2014–2017	14.6.2013	1.9.2013	29.10.2013	1.4.2014	15.8.2014	14.11.2014	27.3.2015	2.9.2015	2.9.2016	31.1.2017	29.9.2017
Western Spinebill *Acanthorhynchus superciliosus*		√	√	√												
Brown Honeyeater *Lichmera indistincta*	√*	√	√	√(*+)	√	√	√	√	√+	√	√	+	√	√	+	√
New Holland Honeyeater *Phylidonyris novaehollandiae*	√	√														
White-cheeked Honeyeater *Phylidonyris niger*	√	√	√	√	√	√						√		√	√	√
Western Wattlebird *A. lunulata*			√	√	√											
Red Wattlebird *Anthochaera carunculata*	√*	√*			√	√	√		√	√	√	√	√	√	√	√
Singing Honeyeater *Gavicalis virescens*	√*	√	√		√	√	+	+	+	√	√+		√	√	+	√
Spotted Pardalote *Pardalotus punctatus*	√													√		
Striated Pardalote *P. striatus*	√*	√	√	√	√		√	√		√	√	√	√	√		√
Weebill *Smicrornis brevirostris*	√*	√	√*	√	√		√	√	√	√	√	√	√	√	√	√
Western Gerygone *Gerygone fusca*	√*	√	√*	√	√		√	√	√	√	√	√	√	√	√	√
Broad-tailed Thornbill *Acanthiza apicalis*		√														

Species	1998–2001	2002–2005	2006–2009	2010–2013	2014–2017	14.6.2013	1.9.2013	29.10.2013	1.4.2014	15.8.2014	14.11.2014	27.3.2015	2.9.2015	2.9.2016	31.1.2017	29.9.2017
Yellow-rumped Thornbill *A. chrysorrhoa*	√*	√*	√*	√	√*	√	√	√		√	√	√	√			
Grey Butcherbird *Cracticus torquatus*	√*	√	√	√	√			√	√	√	√	√	√	√	+	√
Australian Magpie *C. tibicen*	√	√	√		√			+	√+	√+		√	+	+	√	√
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	√	√			√	√	√	√	√	√	√	√	√	√	√	√
Varied Sittella *Daphoenositta chrysoptera*	√*	√														
Rufous Whistler *Pachycephala rufiventris*	√*	√	√	√	√	√	√	√	√	√	√	√	√	√		√
Willie Wagtail *Rhipidura leucophrys*	√	√	√	√	√	√			√	√+		+	√+	√		
Grey Fantail *R. albiscapa*	√*	√	√	√*	√					√				√		√

Species	1998–2001	2002–2005	2006–2009	2010–2013	2014–2017	14.6.2013	1.9.2013	29.10.2013	1.4.2014	15.8.2014	14.11.2014	27.3.2015	2.9.2015	2.9.2016	31.1.2017	29.9.2017
Magpie-lark *Grallina cyanoleuca*		√			√				+	+	√	+			√	
Western Raven *Corvus perplexus*	√	√	√	√	√	√	√	√	√	√	√	√+	√		√	√
Welcome Swallow *Hirundo neoxena*	√	√	√	√	√					+						
Tree Martin *Petrochelidon nigricans*	√	√	√	√	√											
Grey-breasted White-eye *Zosterops lateralis*	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√
Mistletoebird *Dicaeum hirundinaceum*		√			√											

Rufous Whistler (Fig. 3). Males and females recorded in all months. On 25.9.2016 MO photographed an apparent immature male which had been banded on its left leg.

Western Raven. Recorded in all months. Flocks of c. 40 and c. 50 observed 5/14 and 6/15 respectively. Seen harassing juvenile Brown Goshawk, Red-tailed Black Cockatoo, Australian Hobby, Tawny Frogmouth, and Carnaby's Cockatoo. In 5/14 seen eating the flesh of fruits of *M. fraseri* and pulling the leaves from *X. preissii* seeking insects, and pulling bark off Tuarts 7/17. Seen collecting sticks 8/17.

Grey-breasted White-eye. Recorded in all months.

Regular/seasonal visitor

Laughing Kookaburra. Breeding. Egg shell found 7/12 and 6/17 (both identified by R.E. Johnstone).

Rainbow Bee-eater. Breeding. Recorded from October to March. Observed 1/04 being chased by Black-faced Cuckoo-shrike and in 12/16 being threatened by a White-cheeked Honeyeater. In 1/05 and 12/09 nesting burrows dug out by foxes. In 11/08 sand dumped on tunnels under construction. On 14.2.16. c. 30–40 birds seen flocking.

Red-tailed Black Cockatoo (Fig. 2). In 6/09 an unfamiliar scream heard; in hindsight attributable to this species. Similarly, Jarrah fruits attacked by unidentified cockatoos found in 7/09 and 8/09 are presumptive of this species. First definitively identified in 12/11. Some 300 birds have roosted to the west of UAB (UWA Sports Park, McGillivray Road) since 2/13. In 4/17 610 birds counted there. First noted investigating a hollow at UAB in 1/14, and a female first seen entering a hollow in 2/14 (various dates), and then frequently thereafter (3/14–9/14; 1/15–3/15, 6/15–7/15, 9/15; 1/16–4/16, 8/16, 10–11/16, 3–4/17, 6/17). Although copulation was observed in UAB in 6/12 and near Brockway Road in 2/15 and 10/17, no nesting has occurred at UAB. Pairs and family groups show continuing interest in a mature Jarrah with a hollow that is the closest tree encountered after leaving the roosting site in the mornings. Hollows in other trees, both Jarrah and Tuart, are also investigated and entered. A Tuart hollow was entered in 7/14, 11/14, 3/15, 4/15, and 4/17.

Birds are more often recorded from January to May than from June to December. However, seldom recorded 6–9/17, but again recorded more often in 10/17.

This species has been seen drinking water from a canal at a turf farm (within the north-west sector of UAB) in 8/14 and 2/15; The canal has since been removed. Seen drinking water from puddles on the ground in 10/14, and from puddles on a plastic sheet in 5/17.

The main food item consumed at

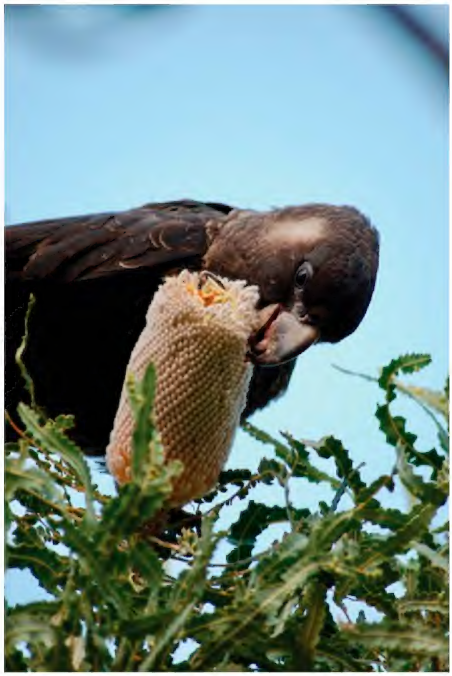

Figure 2. Some important bird species. Top left: Red-tailed Black Cockatoo investigating a hollow in a Jarrah tree. Top right: Carnaby's Cockatoo feeding on a *B. prionotes* conflorescence. Left: Brown Goshawk.

UAB is Jarrah seed (numerous observations since 3/13). Seldom eating seed of *X. preissii* (1/15), Sheoak *Allocasuarina fraseriana* (1/16), *Banksia attenuata* (11/16), *B. menziesii* (2/17), and Tuart (10/14, 8/16). No records of consumption of nectar from banksia or other species. To the immediate west of UAB recorded eating olives 1–2/17.

Interactions with other species are surprisingly numerous: Observed chasing Western Raven (6–7/14, 6/15) and Australian

Kestrel (11/14) and threatening Little Corella (6/14), Australian Kestrel (11/14) and Australian Hobby (1/16). Seen being chased or threatened by Australian Magpie (6/14, 8/14), Little Corella (7/14, 9/14, 6/15), Galah (7/14,10/16 – this last being of a female in a hollow, 7/15, 4/17), Australian Raven (8/14, 4/15, 6/15), Rainbow Lorikeet (8/14, 4/17), Brown Goshawk (1/16), and Australian Kestrel (1/16).

Little Corella. First recorded in 9/05. No evidence of nesting in UAB, though previously recorded nesting by Berry and Berry (2008). However, noted in a hollow in 3/17. Seen eating olives to the immediate west of UAB.

Carnaby's Cockatoo (Fig. 2). Recorded in all months, but least from August to January. Flocks of 100–300 not unusual during the period March–June, especially in April. Although females have been seen entering hollows in 8–9/13, 2/14, 4–5/14, 3–4/15, 6–7/15 and 7/17, no breeding has been recorded in UAB. Seldom observed eating the seeds of Jarrah (7–8/09, 6–7/13, 4–5/14), Marri (once), Harsh Hakea *Hakea prostrata* (2/14, 4/15) and *X. preissii* (4–5/13). Seeds of *Banksia prionotes* and *B. attenuata* are more commonly eaten. Nectar is frequently extracted from conflorescences of *B. menziesii* and *B. prionotes*, which are often bitten off and the nectar is extracted when the bird is on the ground. Nectar and seeds from Parrot Bush *Dryandra sessilis* are also taken. Seen searching for grubs in dead branches of Orange Wattle *Acacia saligna* (5/11, 2/14, 4/14, 4/16, 7/16) and eating rust fungus galls. Also seen searching under bark (removed) of Tuart (4, 7, 9/15; 4/17) and Jarrah, and occasionally eating curled young foliage of *B. menziesii* (6/10). Birds drinking water from the canal at the turf farm in 3–4/15. Harassed by Little Corella (3/13), Australian Magpie (4/13), and Western Raven (5/14, 6/15).

White-cheeked Honeyeater. First recorded 4/03. Recorded in all months, least in February, June–July, and October–December.

Singing Honeyeater. Recorded in all months (except October). More often heard calling from outside UAB. According to Stranger (1998, 2003, 2008), this species in the 1950s was uncommon, occurring only in coastal vegetation and not in Banksia woodland near Perry Lakes or in bushland between southern Wembley and the coastal dunes.

Australian Magpie. Perhaps better considered as an irregular visitor. Mostly recorded from May to September. Seen attacking a Tawny Frogmouth in 8/03.

Black-faced Cuckoo-shrike. Recorded in all months.

Willie Wagtail. Recorded in all months. Nested in 9–10/15.

Grey Fantail. Recorded in all months (except March), but not recorded on each visit. Nest seen 12/11.

Vagrant/Irregular Visitor

Australian Shelduck. Excluding flyovers, seen 6/06 (2 birds perched in Jarrah tree), 9/11 (2 males, 1 female perched in tree and harassed by Little Corella), numerous records 6 & 8/14 perched in Jarrah trees and being harassed by Western Ravens; also noted 5/15, 8/15, 9/15, 9/17.

Australian Wood Duck. Recorded 6/13, 7/13 (c. 10), 6/14 (2, 1 of which entered a hollow in Jarrah), 7–9/14, 9/16 (harassed by a Red-tailed Black Cockatoo), 8/14, 4/17 (at a hollow in Jarrah), 9/17.

Pacific Black Duck. 9/13 only.

Australian White Ibis. Recorded occasionally in 2013–17.

Straw-necked Ibis. Seen feeding on ground in 1/14 soon after wildfire.

White-faced Heron. 7/14, one bird perched.

Black-shouldered Kite. Recorded 2/07 (1 bird on 2 days), 8/15 (1 bird, perched on Jarrah), 2/16, and 5/17 (1, to west of UAB).

Little Eagle. Infrequent. Until the 2002 wildfire, bred at UAB. Since then, mostly recorded in January–April. Chased by a raptor (Collared Sparrowhawk?) 11/10 and by Western Ravens 5/11, 2/15, and 6/17.

Collared Sparrowhawk. Prior to 2012, records likely to be confused with Brown Goshawk. Birds with long middle toes have been seen, as have individuals with a notched tail. Definitely identified 11/07 and 11/09. Nested in 11/07 on the south side of UAB, resulting in 3 young.

Domestic Pigeon. Seen 11/14 and 3/15.

Spotted Turtle-dove. Noted 10/13, 8/14, 11/14, 1/17, 8–9/17.

Laughing Turtle-dove. Noted only in 4/17 and 9/17 (1 bird).

Common Bronzewing. Recorded on 4 dates in 7/14 (2 birds) and once in 6/17 (2 birds). One of the birds seen in 2014 was swooped by a Brown Goshawk.

Shining Bronze Cuckoo. Recorded 8/17 and 9/17 (1 bird on 2 days).

Pallid Cuckoo. Recorded 7/02, 8/02 (2–3 sub-adults), 9/17.

Barn Owl. One found dead in 2/17.

Sacred Kingfisher. Recorded 1/04 and 10/17 (twice).

Australian Kestrel. Recorded 2014–16, but mostly just outside UAB. Seen in UAB in 11/14 (twice), 8/15 (copulating), and 9/15. Harassed by Willie Wagtail and Red-tailed Black Cockatoo.

Australian Hobby. Seldom noted: 6/04 (2 birds), 6/07, 7/08, 12/09, 9/10, 1/13, 2/14, 1–2/16, 4/16, 7/16, 5/17, 7/17. Harrassed by a Rainbow Lorikeet and a Red-tailed Black Cockatoo. Mutually aggressive encounters seen with Red-tailed Black Cockatoo, and with Australian Magpie.

Peregrine Falcon. Recorded 2/15 (twice), 7/15.

Figure 3. Species considered to be declining in bushland in the Perth metropolitan region. Upper left: Yellow-rumped Thornbill Upper right: Rufous Whistler Lower left: Striated Pardalote Lower right: Western Gerygone

Galah. Recorded 4/02 (5 birds), 7/06 (2), 2/10, 11/14, 6/15 (3, in hollows), 7/15 (harassing Red-tailed Black Cockatoo), 9/16, 1/17, 3/17 (investigating hollows), 6/17.

Australian Ringneck. Recorded 4/02, 7–9/02, 2–3/03, 5–6/04,

8/04 (many fighting over hollows), 7/16 (3), 9/16, 9/17.

Western Spinebill. Noted 1/04, 7/05, 3/06, 11/06, 3/07, 4/08 (on *B. prionotes* conflorescence), 4/11 (on *B. menziesii* conflorescence), 6/11 (male).

New Holland Honeyeater. 7/04 is the only definite record.

Western Wattlebird. Recorded 2/08, 5/11, 4/16 (2 birds).

Spotted Pardalote. 9/16 (heard).

Broad-tailed Thornbill. Recorded 3/02 (with Yellow-rumped Thornbills), 6/02.

Varied Sittella. Recorded 8/02 (2 dates), 9/05.

Magpie-lark. Only 8 records in UAB.

Welcome Swallow. Recorded in UAB on only 7 occasions, 4 of which were in July.

Tree Martin. Although recorded in all months (except August–October), its occurrence is sporadic and no birds have been seen entering hollows.

Mistletoebird. Recorded 7/03 (on 2 dates; on one a female), 9/15, 6/16 (on 2 dates, on one a male), 8/16 (a juvenile), 12/16 (a juvenile on Blackberry Nightshade *Solanum nigrum*, presumably seeking fruits), 8/17 (a male). No mistletoe species occur at UAB.

Uncertain status

Painted Button-quail. 'Quail' (assumed to be this species) were disturbed into flight on 3/03, 4/03 (2 birds), 2/04 (3), 5/04 (2), 7/04, 8/04, 9/04 (2), 1/05 (3), 2/05, 1/06, 3/06, 7/06 (2), 7/15, 9/15, 1/16, 6/17.

Boobook Owl. Recorded 8/10 (1, flushed from the skirt of *X. preissii*) and 10/10 (just outside UAB). Probably an overlooked resident species.

Tawny Frogmouth. Recorded 7/03 (harassed by Western Ravens), 12/11 (to immediate south of UAB), 10/15 (to immediate north of UAB – 1 pair nested in Lawler Park and had 3 young in the nest). Possibly an overlooked resident species.

Variegated Fairy-wren. Recorded 7/05, 1/07, 9/07, 11/07, 6/11 (all to immediate south of UAB), 2/10, 1/11, 2/12, 11/14 (all photographed on site), and 3/12, 7/15, 8/15, 11/15, 1/16. Probably an unsuccessful colonist because of habitat unsuitability (absence of dense thickets). Since the 1/14 wildfire, however, wattle thickets have become extensive and by 9/17 well-developed. This species may establish in the near-future.

DISCUSSION

Lacking a baseline, we cannot be sure of the original (1829) size and composition of the avifauna of UAB when it was still part of a much greater extent of bushland (probably until the 1950s). At present, bushland closest to UAB is Shenton Bushland (c. 580 m distant, area 19.7 ha), followed by a small unnamed area south of

the basketball and rugby buildings (c. 970 m), Bold Park (c. 970 m, 361.7 ha), and bushland near settler's cottage at Herdsman Lake (c. 1 km, 22.6 ha). Between April 2014 and March 2017 the integrity of the linkage between Shenton Bushland and UAB provided by the western (70 m-wide) corridor was all but destroyed by building activity. The recently-closed (1893–2014) Royal Perth Hospital Shenton Park annexe on the eastern side of Bedbrook Place is being redeveloped for high density housing (c. 1100 dwellings, including multi-storey apartment blocks). The narrow (< 70 m-wide) corridor to the east of Bedbrook Place joins with a small (3.4 ha) bushland remnant that is part of this development. The future of this bushland linkage is threatened because approval was given for buildings within the bushland, necessitating its fracture into cells.

Although the avifauna of UAB is now but a shadow of what it was in the 1950s, it is notable for three iconic species and the occurrence of other species which are now largely restricted to bushland remnants. Two of the iconic species are listed under the Wildlife Conservation Act (Minister for Environment 2017) as fauna that is rare or likely to become extinct: Carnaby's Cockatoo (Endangered), and Red-tailed Black Cockatoo (subspecies *naso*, Vulnerable). The third iconic species, Brown Goshawk, is a wide-ranging raptor that nests only in trees situated in bushland. Also well-represented in UAB are the Rainbow Bee-eater, Striated Pardalote, Weebill, Western Gerygone, Yellow-rumped Thornbill, and Rufous Whistler, species regarded as declining in the Perth metropolitan region (Government of Western Australia 2000: 63, Moore and Barrett in press). These, and others, regarded as regionally significant declining species (Table 1) highlight the linkage role between the three bushland areas for dispersal, seasonal movement, and maintenance of gene flow. This emphasises the importance of maintaining avian diversity.

We are unable to draw valid conclusions about any change in status of species since the 1998–2001 304-day study of Berry and Berry (2008). This is because the focus of that study was reptiles and frogs. Their recording of bird species was incidental and the data were collected in a way that does not allow us to calculate the frequency of occurrence of bird species (P. Berry pers. comm.). In addition, their observations were made only from September/October to February/March.

In the period 1998–2001, Berry and Berry (2008) recorded 40 bird species, compared with 58 species for the period 2002–17. This difference is not surprising for three reasons. First, the former period is shorter than the latter. Second, it involved 304 visits to UAB compared with our >1000 visits. Finally, the former study

was seasonal in its coverage because of the activity patterns of reptiles. In contrast, Berry and Berry (2008) record breeding of 15 bird species at UAB, more than the nine species recorded by us. It is highly likely that all 12 of the species recorded by us as resident/regularly occurring breed at UAB; at least three of the regular/seasonal visitors breed there, and at least one of the vagrant/irregular visitors has bred there. In addition, all four of the species deemed to be of uncertain status have probably bred at UAB.

For three reasons we expect more species to be added to the UAB bird list, given that the species accumulation curves presented in Fig. 4 have not yet reached a plateau. First, on our last joint visit to UAB (29.9.2017, not included in Fig. 4), we added a previously unrecorded species, the Shining Bronze Cuckoo. Second, Bold Park has at least 11 species not yet recorded at UAB. These species comprise the Whistling Kite *Haliastur sphenurus*, Horsfield's Bronze Cuckoo *Chrysococcyx basalis*, Fan-tailed Cuckoo *Cacomantis flabelliformis*, Elegant Parrot *Neophema elegans*, Splendid Fairy-wren *Malurus splendens*, Tawny-crowned Honeyeater *Glyciphila melanops*, White-browed Scrub-wren *Sericornis frontalis*, Western Thornbill *Acanthiza inornata*, White-winged Triller *Lalage tricolor*, Grey Shrike-thrush *Colluricincla harmonica*, and White-backed Swallow *Cheramoeca leucosterna*. Finally, during the past 3–4 years the Rufous Treecreeper *Climacteris rufus*, Western white-naped Honeyeater *Melithreptus chloropsis*, and Brown Songlark *Megalurus cruralis* have been recorded (as single individuals) at Herdsman Lake (T. Kannis, per. comm.).

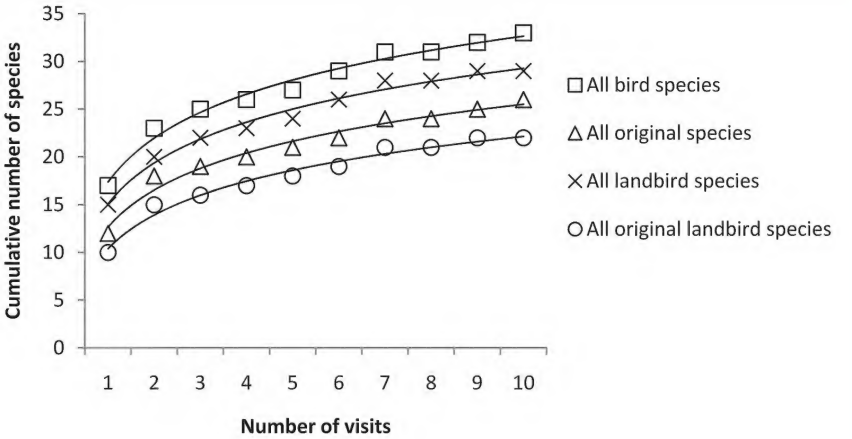

Figure 4. Species accumulation curves, based on the first 10 visits by IA.

The surprising feature of UAB is the depauperate honeyeater fauna, with only the Red Wattlebird, Brown Honeyeater, White-cheeked Honeyeater, and Singing Honeyeater being regularly recorded. Yet, nectar in banksia flowers is available continuously throughout the year (*B. prionotes*, January–August; *B. menziesii*, February–October; *B. attenuata*, October–February). Thus, lack of nectar does not explain why the Western Spinebill and Western Wattlebird are no longer regular seasonal visitors to, or residents of, UAB.

Similarly, the foliage of understorey species present at UAB is extensive, so a lack of foraging habitat is unlikely to explain the absence of understory-dependent species such as the Broad-tailed Thornbill and Western Thornbill *Acanthiza inornata*.

The Western Spinebill, Western Wattlebird, Broad-tailed Thornbill and Western Thornbill, now absent from UAB, are now also scarce (I. Abbott pers. obs., 2008–17) at Bold Park and the more distant (at 1.9 km) Kings Park (320.8 ha), the largest bushland remnants close to UAB. Thus, it seems unlikely that these four species will be able to recolonise UAB.

Because bird banding has not, to our knowledge, been undertaken at UAB, it is difficult to assess the extent of movement of individual birds between UAB, Kings Park, Bold Park, Shenton Park, Hollywood Reserve, Herdsman Lake and other bushland remnants. Bird banding has taken place at Bold Park since 1989 and at Herdsman Lake since 1974 (though not continuously). It would be useful to conduct banding of birds at all bushland remnants within 3 km of UAB in order to obtain information about the comparative dispersal ability of the rarer bushland bird species, particularly the extent of movement of individual birds between UAB and other bushland remnants. Given that most fledglings have to disperse eventually from the territory occupied by their parents, we believe that movement of birds between bushland remnants is more extensive and frequent than reported. Berry and Berry (2008) have previously brought attention to the dynamic nature of populations of many bird species in the western suburbs of Perth. Abbott and Wills (2016) collated records of a large number of landbird species vagrant to Rottnest Island – a further indication of the dispersive abilities of these species.

Before European settlement the avifauna and its habitat would have been subject to several kinds of disturbance. Natural factors include fires ignited by lightning strike, drought, storm-force winds, hailstorms, and predation by sand monitors (*Varanus gouldii*), chuditch (*Dasyurus geoffroii*), wambengers (*Phascogale tapoatafa*), and dingoes (*Canis familiaris*). Disturbances caused by humans comprised fires ignited by Noongars,

thought to have been in small patches, with a return time of fire of 3–7 years (Abbott 2003, Ward 2010), and predation of some bird species by Noongars (Stranger undated, Stranger 2010). All of these factors resulted in only transient destruction of bird habitat and of individual birds.

Once some of the pre-1829 causes of disturbance were eliminated around Perth, they were replaced by new ones, including the establishment of feral cats in c. 1850 (Abbott 2002) and foxes in the 1930s (Abbott 2008). Settlement by Europeans, initially for farming, resulted in permanent but patchy destruction of bird habitat (Abbott 2003). The link to Kings Park began to be severed in the 1880s when the suburb of Subiaco was surveyed and its fracture intensified with the 1890s gold rushes (Spillman 1985). With subsequent increase in population in the metropolitan region, loss of bird habitat became more widespread as the suburbs of Jolimont (1890s, 1940s), Shenton Park (1910, 1940s), Wembley (1930s), Nedlands (1930s), Floreat (1940s), and Daglish (1950s) were created and fully developed for housing and public open space (Williams 1984). UAB then became progressively smaller and more isolated from other remnants of bushland, resulting in more or less permanent disconnection of some bird populations, their diminished persistence in the suburban landscape, and eventual local extinction.

Many of the smaller bushland bird species that are now vagrant to UAB (Western Spinebill, Broad-tailed Thornbill, Varied Sittella) are also very scarce at Herdsman Lake, Bold Park, and Kings Park (Recher 2004, Rutherford 2010, HLBBG 2015-2016, BPBBG 2017, I. Abbott pers. obs. 2008–17). Their persistence in these bushland remnants seems imperilled. Unprecedented (at least in historic times) events can also impact on bushland and bird species. For example, on 22 March 2010 an intense hailstorm caused widespread damage in Kings Park, defoliating trees and killing many Carnaby's Cockatoos (Webb 2010, Saunders *et al.* 2011). UAB was on the edge of this storm and suffered little damage.

Introduction of plant species from Britain and South Africa, especially Perennial Veldt Grass, together with the demise of Noongar burning by c. 1860 and its replacement by high intensity (wild)fire, led to degradation of bird habitat. Before suburbanisation, wildfires would have burnt until either rain occurred or previously-burnt bushland (1–3 years since the last fire) confronted the path of the fire. At UAB there have been four wildfires since 2000, namely a series of three fires on 6, 7 and 9 January 2002 and one on 11 January 2014. Historical imaging of UAB on Google Earth reveals that the last fire burned c. 95% of UAB. The introduced veldt grass, once cured by the summer heat and lack of rainfall, provides a

readily-combustible fuel that promotes rapid spread of wildfire before the fire brigade can attend and extinguish the fire.

As mentioned previously, UWA proposes to destroy much of the bird habitat present in UAB. The possibility of residential housing was facilitated in the 2000s when a 1 km buffer zone around the adjacent waste water (sewage) treatment plant was reduced to 500 m, thereby including a substantial portion of UAB. However, on 16 September 2016 the Australian Government listed 'Banksia Woodlands of the Swan Coastal Plain ecological community' (characterised by plant species-rich ground cover, emergent trees, and banksia species comprising the mid-storey) as an endangered threatened ecological community under the Environmental Protection and Biodiversity Conservation Act (Australian Government 2016).

UWA cannot build housing within the odour buffer. The land within this buffer is part bushland (c. 4 ha) and part-cleared land that is the UWA agricultural field station that extends west to Brockway Road. In 2003, UWA proposed to clear all but 12 ha of UAB (EPA 2003). A revised proposal would have had a similar outcome (EPA 2007). The current proposal (UWA 2016) is for 12.1 ha for housing, 13.9 ha for conservation, and 3.1 ha for public open space. All of these proposals would have destroyed most of the vegetation dominated by Acorn Banksia, Slender Banksia, and many of the Tuart trees. UWA continues to reject community requests to retain UAB as a contribution to improving biodiversity conservation in the western suburbs of Perth. Indeed, UAB currently experiences passive neglect by UWA. Apart from annual maintenance of fire breaks along the perimeter and through the bushland, there is no control of veldt grass and other invasive weeds. The occurrence of wildfires since 2000 has provided an opportunity to treat the regeneration of veldt grass and other invasive weeds but no weed management has been undertaken by the university.

On-ground management of Shenton Bushland by the City of Nedlands since 1993 demonstrates what can be accomplished with focused weed control by community members supported by local government. Selective spraying of Perennial Veldt Grass during winter of 1999–2002 reduced its cover from >60% to <5% in 2002 (Brown and Brooks 2002: 93).

Herbicide control of Perennial Veldt Grass has been shown to increase the numbers of bird species and individual birds present in banksia woodland relative to untreated banksia woodland (Moore and Barrett in press). Restoration of bushland habitat (by planting thousands of native species) around parts of Lake Claremont since 2009 has also facilitated colonisation by

several small species of birds (I. Abbott, pers. obs.). All of these actions provide great encouragement for conserving and then repairing the bushland of the UWA site at Underwood Avenue.

The position of the Friends of Underwood Avenue and the Urban Bushland Council of WA is to exclude deliberate burning of bushland. Suppression of wildfire is currently reliant on the Department of Fire and Emergency Services being alerted and attending in time to extinguish the fire. The alternative view is that wildfire mitigation through regular strategic patch burning of ground vegetation coupled with herbicide control of veldt grass (using Fusilade©) should encourage the reestablishment of the native annual grass *Austrostipa compressa* and other native plant species. Current research being conducted in Kings Park and Bold Park by the Botanical Gardens and Parks Authority will provide valuable information about the cost and practicality of this approach.

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EVIDENCE OF POLLINATION BY SEXUAL DECEPTION IN THE ENDANGERED SPIDER ORCHID *CALADENIA WILLIAMSIAE*

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ABSTRACT

Caladenia williamsiae is a morphologically unusual spider orchid restricted to a small number of populations in the western and southern wheatbelt. Here, I present evidence that *C. williamsiae* is pollinated by sexual deception of the wasp *Aeolothynnus innocuus* (Thynninae), a member of a genus not previously known to be involved in pollination of *Caladenia* in Western Australia. While pollen deposition was not observed, members of this wasp species were the only visitors to flowers and some individuals carried pollen of *C. williamsiae*. Further, all individuals exhibited the sterotyped behaviour associated with sexually deceived thynnine wasp pollinators, in many cases attempting copulation with the flower. Floral dissections showed that the sexual attractant is produced both from the labellum and terminal osmophores on the sepals.

INTRODUCTION

Pollination by sexual deception typically involves the chemical and sometimes visual mimicry of female insects leading to the attraction of sexually excited males (Schiestl *et al.* 1999, 2003; Bohman *et al.* 2014). While recently demonstrated to occur in the Asteraceae and Iridaceae (Ellis and Johnson 2010; Vereecken *et al.* 2012), this strategy is primarily restricted to the orchids where it is now known from over 20 genera worldwide (Gaskett 2011; Phillips *et al.* 2014b). Australia is exceptional among the world's orchid floras in that a large number of genera have members that are pollinated by sexual deception (Coleman 1928; Stoutamire 1974;

Peakall 1989; Bower 1996; Phillips *et al.* 2014b).

Among orchids, the diverse primarily southern Australian genus *Caladenia* appears to be unique in that it contains both species pollinated by food foraging insects, and numerous species pollinated via sexual deception (Stoutamire 1983; Phillips *et al.* 2009). Thus far, all known cases of sexual deception in *Caladenia* involve pollination by thynnine wasps (Phillips *et al.* 2009), a diverse group of solitary wasps. Long distance attraction of sexually deceived thynnines is by chemical cues (Stoutamire 1983), which typically differ between pollinator species (Bohman *et al.* 2017; Xu *et al.* 2017). In sexually deceptive *Caladenia*, the flower often has swollen osmophores on the sepals, aggregations of dark calli on the labellum, and dull green or red colouration (Stoutamire 1983; Phillips *et al.* 2009). Nonetheless, exceptions are known to this trend, with some species of sexually deceptive *Caladenia* being large and brightly coloured, even bearing superficial resemblance to species pollinated by food foraging insects (Phillips *et al.* 2017).

As a by-product of mimicking the specific sex pheromones of insects, sexually deceptive orchids are highly specialised, with often just a single known pollinator species (Paulus and Gack 1990; Peakall *et al.* 2010; Gaskett 2011; Phillips *et al.* 2014a, 2017). This specialisation leaves the orchids vulnerable to rarity through having a pollinator that is intrinsically rare or declining in abundance. For example, in *Caladenia huegelii* the apparent absence or rarity of its pollinator from most areas of suitable habitat within its geographic range is one the primary concerns for the preservation of the species (Phillips *et al.* 2015).

Here I investigated the pollination of the critically endangered spider orchid *Caladenia williamsiae* Hopper & A.P. Brown, which, based on its swollen sepaline osmophores and dull colouration, was predicted to be pollinated by sexual deception of thynnine wasps (Figure 1). While originally known from woodland and lateritic heathland in the western wheatbelt (Brown *et al.* 2013), *C. williamsiae* has recently been discovered in mallee in the southern wheatbelt (A. Brown pers. comm.). Based on morphology, *C. williamsiae* appears to have no extant close relatives (Hopper and Brown 2001). Specifically, I aimed to (i) test if *C. williamsiae* is sexually deceptive (ii) identify the pollinator species (iii) document its behaviour on the flower and (iv) determine which part of the flower produces the sexual attractant.

METHOD

Pollinator observations were undertaken between 10:40 am and 3:30 pm on the 14th of

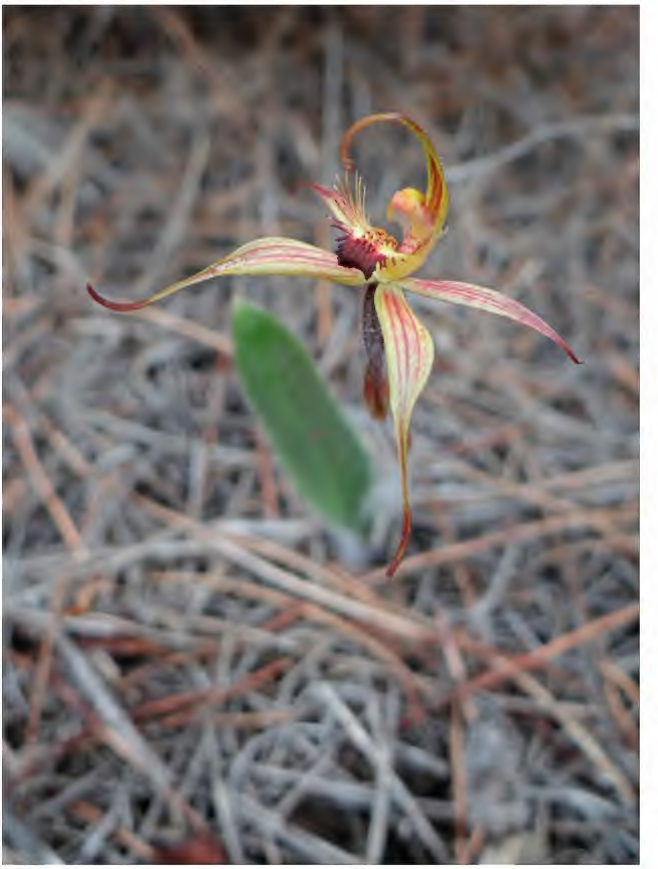

Figure 1. *Caladenia williamsiae* growing at the study site. Sexual attractant was produced from the labellum and the terminal osmophores of the sepals.

August 2016 at a single site near Brookton, Western Australia (population represented in the Western Australian herbarium by the collection FH 1993 PERTH 06751970). As a requirement of the permit for working on threatened flora, precise location details have been withheld. A survey of the population during the cool of the morning before pollinators became active confirmed that there was yet to be pollination in the population during the 2016 flowering period.

Pollinator observations were undertaken using the pollinator baiting method where picked 'bait' flowers are moved to new positions in the landscape to generate new pollinator responses (Stoutamire 1974; Peakall 1990). Two freshly picked flowers were used for baiting, which were kept fresh in a vial of water. In total, 31 3-minute periods of

observation were undertaken, at random positions within the *C. williamsiae* population. For each floral visitor, it was recorded if they alighted on the flower, where they first landed, if they attempted copulation, with which part of the flower they attempted copulation and if pollen was removed. Representatives of all species of floral visitor were collected for identification.

Floral dissections were used to determine from which part of the flower the sexual attractant originated. For each of three flowers, two 3-minute trials were undertaken baiting simultaneously with (i) the labellum (ii) the osmophores on the sepal tips (iii) the remaining floral parts. Floral parts were held in position by being pinned to a wooden skewer. The skewers holding each floral part were inserted vertically into the ground in random order in a line, approximately 50 cm apart. For each responding pollinator, it was recorded if they landed and if they attempted copulation, either with the head of the pin or the clubs themselves.

RESULTS

Across the 31 baiting trials, there were responses from 35 wasp individuals all belonging to the thynnine wasp *Aeolothynnus innocuus* (average = 1.1 wasps per trial). As is typical for sexually deceived thynnine wasps, each of these wasps exhibited stereotyped odour-tracking behaviour where the wasps engage in a steady zig-zag flight towards the flower. Of the 35 responding wasps, three individuals carried pollen on the dorsal side of their thorax that matched the appearance of the pollinia of *C. williamsiae* rather than the co-flowering *Caladenia reptans* Lindl.. Out of the 35 wasps, 27 alighted on *C. williamsiae*, most commonly landing on the osmophores of either the lateral sepals (9 individuals), the osmorphores of the dorsal sepal (5), or the labellum (5). The remaining wasps landed on either the column, stem, or non-glandular parts of the petals and sepals. Copulation was observed in eleven individuals, with copulation being attempted with the lateral sepal osmophores (5 individuals), dorsal sepal osmophore (4) and labellum (3). None of the individuals observed moved into the correct position to remove pollen.

In each of the three dissected flowers, wasps were attracted to both the osmophores and the labellum, but not the remainder of the flower. Across the three flowers, 29 wasps were attracted to the osmophores and 10 to the labellum. Similarly, across the three flowers, 23 wasps landed on the osmophores, while only five landed on the labellum. Attempted copulation was observed a total of four times, in each case with the osmophores.

DISCUSSION

Numerous copulation attempts with *C. williamsiae* demonstrated that *A. innocuus* is attracted to the flower via sexual deception. While the deposition of pollen was not observed, strong evidence was found that *A. innocuus* is likely to be the primary pollinator of *C. williamsiae* at this site. During pollinator baiting trials within the largest known population of the orchid, *A. innocuus* was the only floral visitor observed, with three individuals observed carrying pollen. It has previously been shown in *Caladenia* that wasps capable of removing pollen are also capable of achieving deposition (Phillips *et al.*, 2009), due to the pollen being held immediately adjacent to the stigma. Further, in orchids pollinated by sexual deception of thynnine wasps there is typically a solitary pollinator species in any given population of orchids (Phillips *et al.* 2009; Peakall *et al.* 2010; Phillips *et al.* 2014a, 2017).

While a member of the genus *Aeolothynnus* is known to pollinate *Caladenia toxochila* and *Caladenia concinna* in south-eastern Australia (Bower 2001), this is the first record of this genus pollinating a Western Australian *Caladenia*. This observation continues the trend of morphologically unique *Caladenia* using atypical pollinator genera. Other examples of morphologically unique *Caladenia* using unusual pollinator genera include *Caladenia crebra*, the only *Caladenia* known to be regularly pollinated by a wasp in the genus *Campylothynnus* (Bohman *et al.* 2017), and *Caladenia macrostylis*, the only species in its subgenus pollinated by a member of *Tachynomia* (Phillips *et al.* 2017). These observations have led to the hypothesis that these wasp genera may be less conducive to pollinator-mediated speciation compared with the pollinators of more diverse groups of orchids (Phillips *et al.* 2017).

Floral dissections showed that in *C. williamsiae* the sexual attractant is released from both the labellum and the terminal glands on the sepals. This pattern is also seen in members of the *Caladenia tentaculata* complex from both south-eastern and south-western Australia (Peakall and Beattie 1996; R. Phillips unpublished data). However, some other members of *Caladenia* subgenus *Calonema*, to which *C. williamsiae* belongs, show the surprising pattern of releasing the sexual attractant from the terminal glands only, leading to infrequent sexual attraction to the labellum (e.g. *Caladenia pectinata*, Phillips *et al.* 2013). Work is ongoing to try and understand both how these different forms of odour release affect pollinator behaviour, and their potential to affect floral evolution in *Caladenia*.

The effectiveness of pollinator baiting in *C. williamsiae* suggests that this method could be used to conduct pollinator surveys to aid in identifying sites for the

establishment of new populations of this highly endangered orchid. Pollinator baiting has been used successfully to understand the role of pollinators in rarity of Western Australian orchids (Phillips *et al.* 2014a; 2015), and establish new sites suitable for conservation translocations in eastern Australia (Reiter *et al.* 2017; see IUCN 2013 for definition of conservation translocation). While conservation translocations have been done on only a small scale in Western Australian orchids, successful large-scale conservation translocations with *Caladenia* in eastern Australia (see Reiter *et al.* 2016) suggest that should additional sites be located with suitable habitat and a population of the pollinator, that this could be an effective approach for the conservation of *C. williamsiae*.

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FLORA OF THE SWAN COASTAL PLAIN FOOTHILLS PART 2: BANCELL ROAD RESERVE

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ABSTRACT

Bancell Road Reserve near Yarloop preserves a remnant of the Jarrah-Marri woodland that occurs on colluvial lateritic spurs that once were a common feature of the Ridge Hill Shelf between Waroona and Brunswick. A flora of 188 taxa, including a declared rare sedge, was recorded within the reserve.

INTRODUCTION

The Foothills (Ridge Hill Shelf) of the Swan Coastal Plain IBRA region (Macarthur and Bettenay 1960, Government of WA 2000, and Department of Environment and Water Resources 2007) are the gentle slopes of colluvial sands, loams and clays with intrusions of gravel (at surface or depth) that derive from the Darling Plateau and abut the granitic slopes of the Darling Escarpment. The Foothills have very high levels of clearing for agriculture being of low relief, relatively fertile and better drained than the adjacent Pinjarra Plain. It is estimated that the Foothills are approximately 97% cleared, making any remnant of high regional conservation value.

This paper the second in this series (Keighery and Keighery 2015) describes the remnant bushland of Bancell Road Reserve (Reserve 11160; approximately 7 ha., see Figure 1).

Beard (1979) in his discussion of the vegetation of the Ridge Hill Shelf, which he made a separate subsystem comprising Jarrah-Marri Forest with an understory tree layer of *Banksia grandis* and *Allocasuarina fraseriana* noted that:

> "A good relic example of this vegetation remains in a small crown reserve running north from Bancell Road and 1.5 km east of the (SW) Highway."

Strangely this reserve was not mentioned in the System Six

Figure 1. Location of Bancell Road Reserve.

report (DCE 1983), and subsequently most of the reserve has been mined out for gravel, resulting in the complete destruction of most of the natural vegetation of the reserve. Unfortunately no pre-mining survey was carried out and this report endeavours to describe the remaining values of this once unique area.

SURVEY METHOD

Survey work was undertaken in Bancell Road Reserve over several flowering seasons from 1995 to 2004. Two floristic quadrats were established in the bushland and opportunistic plant collections, that is, collections made outside set quadrats, were made during foot traverse at various times of the year. The species present in the relatively intact areas of bushland were observed, not the areas of severe localised disturbance associated with mining. Voucher collections are deposited in PERTH.

Nomenclature generally follows that used in FloraBase (Western Australian Herbarium 1998–), or in the most recent revisions. Conservation status of the flora is assigned in Smith (2017) as per Table 1.

Table 1. Categories of Conservation Listed Flora according to the degree of perceived threat

Category	Definition
P1 (Poorly known Flora)	Taxa with less than 5 populations, which are under threat
P2 (Poorly known Flora)	Taxa with less than 5 populations, at least some of which are not believed to be under immediate threat
P3 (Poorly known Flora)	Taxa with several populations (more than 5), at least some of which are not believed to be under immediate threat
P4 (Rare Taxa)	Taxa which are considered to be adequately surveyed and which while being rare are not currently threatened by any identifiable factors

GEOMORPHOLOGY AND SOILS

Most of Bancell Road Reserve is mapped as part of the Guildford formation (ie Pinjarra Plain, Wilde and Low 1980). However ground inspection shows that it is a lateritic spur with associated colluvial deposits of sands and clays (especially along the central ephemeral creekline).

VEGETATION

The vegetation at Bancell Road Reserve is placed in the Ridge Hill Shelf Subsystem by Beard (1979) and the Forrestfield complex by Heddle *et al.* (1980), both being Foothills/Ridge Hill Shelf units of the Plain. Vegetation of the reserve is Tall open Jarrah (*Eucalyptus marginata*) woodland over *Kingia australis* and/or *Xanthorrhoea preissii* tall shrubland over low mixed shrubland over sedges.

Markey (1997) undertook a regional floristic survey of the northern Darling Scarp terminating at North Dandalup. The sites in Bancell Road Reserve fall into her Super Group 3–Woodlands on lateritic uplands, closest to Community type 9, which is essentially a Jarrah Forest community.

In comparison, the Floristic Survey of the Swan Coastal Plain (Gibson *et al.* 1994) places these sites as part of Supergroup 1: Foothills and Pinjarra Plain and aligned to Floristic Community type 3, most closely aligned to community 3a, which are Marri (*Corymbia calophylla*) Woodlands over *Kingia australis* and sedges.

The Jarrah woodlands of the Ridge Hill Shelf replace the Marri woodlands of the Pinjarra plain, which grow on rises in poorly drained sites and are more closely related to the lateritic plant communities of the Darling Plateau as noted by Markey (1997). The *Eucalyptus lane-poolei* woodlands of the Serpentine area, reported on in Keighery and

Keighery (2015), do not extend south of North Dandalup. The Jarrah woodlands of the Ridge Hill Shelf appear restricted to lateritic spurs in the Harvey area, where they are now found along road verges and in several very small reserves.

Vegetation Condition

Despite the past and continuing gross disturbance of areas of the reserve, the remaining vegetated remnants are in very good to excellent condition suggesting that the reserve could be successfully restored to buffer the largely intact bushland.

FLORA

The remaining bushland in Bancell Road Reserve contains a vascular flora of 188 species (156 natives, 32 weeds) (Table 2). Because of the highly disturbed nature of the area, it is difficult to report on aspects of the composition of the flora apart from species of significance.

Significant Species

The Declared Rare sedge *Tetraria australiensis* occurs in the reserve in areas of intact woodland. This species has previously been located in bushland remnants in Marri woodlands on the eastern side of the Pinjarra Plain geomorphological unit of the Swan Coastal Plain. The Bancell Road Reserve population forms an important link in the scattered disjunct populations of this species recorded from the Mundijong area and south of Busselton.

The reserve contains populations of several species (*Allocasuarina huegeliana*, *Acacia celastrifolia*, *Bossiaea aquifolium* and *Isopogon crithmifolius*) that are very rarely recorded from the Swan Coastal Plain. These species are generally found on the lateritic soils of the Darling Plateau. *Allocasuarina huegeliana* is the only natural population of this species on the Swan Coastal Plain; there is a naturalised population in Kings Park. Similarly *Acacia celastrifolia* is only recorded from the Plain here and in Korijekup Conservation Park at Harvey. *Bossiaea aquifolium* is only recorded on the Plain here, in nearby roadsides and a small reserve north of Harvey. *Isopogon crithmifolius* is the western-most and only record of this species on the Plain.

Other species that are characteristic of the eastern side of the Plain and poorly reserved (Keighery 1999) include – *Grevillea wilsonii*, *Pentapeltis peltigera*, *Gastrolobium dilatatum*, *Hakea cyclocarpa*, *Persoonia elliptica* and *Xanthorrhoea gracilis*.

Weeds

Because of the pervasive past disturbance and dumping of garden refuse and other materials there is a large list of weeds present in the reserve, especially around the margins of the bushland remnants.

The most serious weeds present along the creekline are the

Table 2. Flora List

MONOCOTYLEDONS

ANARTHRIACEAE
Anarthria humilis
Lyginia barbata

ASPARAGACEAE
**Asparagus asparagoides*
Chamaescilla corymbosa
Laxmannia ramosa subsp. *ramosa*
Laxmannia squarrosa
Lomandra nigricans
L. preissii
L. sericea
L. sonderi
L. purpurea
Sowerbaea laxiflora
Thysanotus dichotomus
T. manglesianus
T. patersonii
T. sparteus

CENTROLEPIDACEAE
Aphelia cyperoides
Centrolepis aristata
C. drummondiana

COLCHICACEAE
Burchardia congesta

CYPERACEAE
Cyathochaeta avenacea
Lepidosperma apricola
L. leptostachyum
L. scabrum
L. squamatum
Mesomelaena tetragona
Schoenus curvifolius
S. nanus
Tetraria australiensis (T)
T. octandra
Tricostularia neesii

DASYPOGONACEAE
Dasypogon bromeliifolius
Kingia australis

HAEMODORACEAE
Conostylis setigera
Haemodorum laxum
H. spicatum

HEMEROCALLIDACEAE
Agrostocrinum hirsutum
Caesia micrantha
Dianella revoluta
Tricoryne elatior

HYPOXIDACEAE
Hypoxis glabella

IRIDACEAE
**Babiana angustifolia*
**Chasmanthe floribunda*
**Freesia alba x leichtlinii*
Patersonia juncea
P. occidentalis
**Romulea rosea*
**Watsonia meriana* var. *bulbillifera*

JUNCACEAE
Juncus pauciflorus

ORCHIDACEAE
Caladenia longicauda
**Disa bracteata*
Elythranthera brunonis
Eriochilus dilatatus subsp. *multiflorus*
Microtis media
Pterostylis nana group
P. recurva
P. vittata
Thelymitra crinita
T. vulgaris

POACEAE
**Aira caryophyllea*
Amphipogon turbinatus
Austrostipa semibarbata
A. elegantissima
**Avena barbata*
**Briza maxima*
**Bromus diandrus*
**Eragrostis curvula*
**Ehrharta longiflora*
Microlaena stipoides
Neurachne alopecuroidea
**Pennisetum clandestinum*
Rytidosperma occidentale
Tetrarrhena laevis

Table 2. (cont.)

RESTIONACEAE
Desmocladus asper
D. fascicularis
Hypolaena exsulca

XANTHORRHOEACEAE
Xanthorrhoea gracilis
X. preissii

DICOTYLEDONS

APODANTHACEAE
Pilostyles hamiltonii

AMARANTHACEAE
Alternanthera nodiflora
Ptilotus manglesii

APIACEAE
Daucus glochidiatus
Pentapeltis peltigera
Xanthosia ciliata

ARALIACEAE
Hydrocotyle pilifera var. *glabrata*
Trachymene pilosa

ASTERACEAE
**Arctotheca calendula*
Hyalosperma cotula
**Hypochaeris glabra*
Lagenophora huegelii
Olearia paucidentata
Millotia myosotidifolia
Pterochaeta paniculata
Trichocline spathulata
Quinetia urvillei
**Ursinia anthemoides*

CAMPANULACEAE
Wahlenbergia preissii

CARYOPHYLLACEAE
**Petrorhagia velutina*
**Silene gallica*

CASUARINACEAE
Allocasuarina humilis
A. huegeliana

CELASTRACEAE
Tripterococcus brunonis

CRASSULACEAE
Crassula colorata

DILLENIACEAE
Hibbertia hypericoides

DROSERACEAE
Drosera erythrorhiza
D. glanduligera
D. pallida

ELAEOCARPACEAE
Tetratheca hirsuta

ERICACEAE
Astroloma pallidum
Leucopogon sp. Margaret River (J. Scott 207)

EUPHORBIACEAE
Stachystemon vermicularis

FABACEAE
Acacia celastrifolia
A. dentifera
A. paradoxa
A. preissiana
A. pulchella var *pulchella*
A. saligna
A. sessilis
A. stenoptera
A. teretifolia
Bossiaea angustifolium
B. aquifolium
Daviesia podophylla
D. preissii
D. rhombifolia
Gastrolobium dilatatum
Gompholobium marginatum
Hovea chorizemifolia
Kennedia prostrata
Labichea punctata
**Lupinus angustifolius*
**Ornithopus compressus*
**O. sativus*
Sphaerolobium medium
**Trifolium subterraneum*

GERANIACEAE
**Erodium botrys*

Table 2. (cont.)

GOODENIACEAE
Dampiera linearis
Lechenaultia biloba
Scaevola phlebopetala

LAMIACEAE
Hemiandra pungens

LAURACEAE
Cassytha glabella

LOGANIACEAE
Phyllangium paradoxum

LORANTHACEAE
Nuytsia floribunda

MYOPORACEAE
Myoporum caprarioides

MYRTACEAE
Babingtonia camphorosmae
Corymbia calophylla
Eucalyptus marginata subsp. elegantella
Hypocalymma angustifolia
Kunzea recurva
**Leptospermum laevigatum*
Melaleuca systena

OROBANCHACEAE
**Orobanche minor*
**Parentucellia latifolia*

OXALIDACEAE
Oxalis exilis
**O. glabra*
**O. pes-caprae*

PAPAVERACEAE
**Fumaria capreolata*

PHYLLANTHACEAE
Phyllanthus calycinus

POLYGONACEAE
**Acetosella vulgaris*
Persicaria prostrata
**Rumex crispus*

PRIMULACEAE
**Lysimachia arvensis*

PROTEACEAE
Banksia grandis
Dryandra lindleyana subsp. *lindleyana*
Grevillea wilsonii
Hakea cyclocarpa
H. lissocarpha
H. ruscifolia
Isopogon crithmifolius
I. scaber
Persoonia elliptica
Petrophile striata
Synaphea gracillima
Xylomelum occidentalis

RHAMNACEAE
Trymalium floribundum
T. ledifolium var *rosmarinifolium*

RUBIACEAE
Opercularia vaginata

RUTACEAE
Philotheca spicata

SANTALACEAE
Dodonaea ceratocarpa

SOLANACEAE
**Solanum nigrum*
**S. linnaeum*

STYLIDIACEAE
Levenhookia pusilla
L. stipitata
Stylidium androsaceum
S. piluliferum

THYMELEACEAE
Pimelea suaveolens subsp. *suaveolens*

VIOLACEAE
Hybanthus floribundus subsp. *floribundus*

ZAMIACEAE
Macrozamia fraseri

cormous and bulbous weeds *Oxalis glabra*, **Romulea rosea*, **Sparaxis bulbifera* and **Watsonia meriana* var. *bulbillifera*. Scattered through the bushland the major weeds noted were annual and perennial grasses, **Avena barbata*, **Briza maxima*, **B. minor*, **Eragrostis curvula* and **Ehrharta calycina*.

DISCUSSION

We consider that over 90% of the known flora of the intact portions of the reserve has been recorded, only those species which may still be present in very low numbers may not have been documented.

From the flora recorded here it appears possible that many species currently known to occur on the laterites of the western margin of the Jarrah Forest Bioregion, but absent from the Swan Coastal Plain, could have been present on lateritic spurs on the Ridge Hill Shelf of the Swan Coastal Plain when the area had an intact cover.

Because of the highly cleared nature of the Ridge Hill Shelf, with cessation of disturbance, some rehabilitation and weed control this would still be a valuable conservation reserve. It contains rare flora, the uncommon Jarrah woodland of the Harvey area and is a food source for Forest Red-tailed Black Cockatoos which are regularly seen here.

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WEEDY AND NATURAL DISTRIBUTION OF *ACACIA TRIGONOPHYLLA* (FABACEAE)

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ABSTRACT

The natural distribution of the native species *Acacia trigonophylla* Meisn. is from the Geraldton Sandplains through to the Avon Wheatbelt and the Mallee Bio-Regions and probably also the eastern Jarrah Forest Bio-Region of Western Australia. However, extensive roadside and revegetation plantings, combined with poorly documented collections of these non-native plantings, has given this species an apparently much wider range to the west of its native habitats. The species is beginning to invade wetlands and banksia woodland on the Swan Coastal Plain from these plantings. This species illustrates the need by both curators and researchers to carefully review general herbarium collections before (and after) they are added to databases and several suggestions to undertake this are given. In the case of *Acacia trigonophylla* a search would give the native range in five rather than three bio-regions. This has major implications for planning of restoration projects since this species has the potential to become a weed in natural habitats outside its natural range.

INTRODUCTION

Increasing fragmentation and disturbance of remnant bushland of the Perth Metropolitan Area has greatly increased the need for revegetation, rehabilitation and restoration of these areas. As part of these works, or after natural disturbance such as fire, efforts are made to undertake weed control. Normally most weeds are exotic (Keighery and Longman, 2004) and there is little contention regarding their native/weediness status. However, increasingly new weed occurrences of native Western Australian species outside their natural range are being documented (Keighery, 2013).

Native weeds pose the most difficult issues as many have

been used in roadside and revegetation plantings by State and local government bodies without any appropriate or lasting documentation (Keighery and Keighery, 2015). Collections of these plantings are often found in Australian Herbaria without any indication of their status and are allocated as part of the species' native range. One excellent example of this issue is the subject of this paper – *Acacia trigonophylla*. We use this species as a case study to show why some location records in flora databases are misleading and could lead to serious consequences for the conservation of natural bushland areas on the Swan Coastal Plain.

RESULTS & DISCUSSION

Acacia trigonophylla on the Swan Coastal Plain

The Swan Coastal Plain around Perth has been subject to intensive botanical survey over the past 25 years resulting in several major reports on the flora and vegetation of the area (Powell, 1990; Gibson *et al.*, 1994; Keighery, 1999 and Government of Western Australia, 2000). The area has become one of the best documented in Western Australia, therefore, the finding of a large population of seedling *Acacia trigonophylla* in a wetland in Shirley Balla Nature Reserve in Banjup after a hot summer wildfire (Figure 1) raised a series of concerns. This conspicuous species had never previously been recorded in the area or in any previous survey of bushland on the Swan Coastal Plain as a component of the native flora.

In discussion with the Friends of Warwick Bushland we discovered that *Acacia trigonophylla* was previously recorded by the Friends of Warwick Bushland as invading Warwick Bushland on the Swan Coastal Plain from road-verge and enrichment plantings made in the past by the City of Stirling (City of Joondalup, 2013).

The above-noted second major population of *A. trigonophylla* occurs in Warwick Open Space (Warwick Conservation Area) in the northern suburbs of Perth (Fig. 2). This species was planted over 20 years ago within the reserve in disturbed areas near the margin of the bushland and has since spread (or was also planted) into the middle of the intact bushland. The largest plants are about 5 m wide and 3 m tall with a trunk about 20 cm wide. There are also many seedlings of this species spreading into bushland areas. At Warwick, *A trigonophylla* was planted in a mixture with other WA native plants that were either the wrong provenance or species for a jarrah-banksia woodland habitat (e.g. *Grevillea crithmifolia*, *Hakea lissocarpha*, *H. prostrata* – prostrate form, *H. trifurcata*, *Banksia prionotes*, *B. menziesii* – dwarf form and *Calothamnus quadrifidus*). Some of these other non-local native plants have also become naturalised and are spreading in the bushland.

Figure 1. Flowering plants of *Acacia trigonophylla* in Shirley Balla Reserve (Jandakot; Photo: Vanda Longman).

There is another record from highly disturbed bushland south of Jolimont Primary School (Salasoo 4144, in herb NSW) in suburban Perth. The species is, however, not present in the remnant bushland at the School (Keighery and Keighery, 2013) and has not persisted in the area south of the school where it was planted along the road verge. We believe that *A. trigonophylla* may have been accidently included in nursery-raised seedlings used for

Figure 2. Established plants and seedlings of *Acacia trigonophylla* growing in Warwick Conservation Area within the Shire of Joondalup, Western Australia. Top: Mature plant about 2 m tall. Lower left: Seedling. Lower right: Flowers. (Photos: Mark Brundrett).

bushland regeneration, because it was confused with *A. stenoptera*, another smaller acacia species with similar looking phyllodes.

We have also found this species at a revegetation site in Jandakot Regional Park (Anketell Road, Fig. 3), presumably for the same reason.

Finally, recent surveys have also located the species in wetlands at Harrisdale Reserve in Armadale (Fig. 4), where it and several other

Figure 3. Large old population of *Acacia trigonophylla* in Harrisdale Nature Reserve. (Armadale, Photo: Karen Jackson).

species are invading wetlands from adjacent road verge plantings.

All of the occurrences of this species in bushland on the Swan Coastal Plain can be traced back to in situ or adjacent plantings of this non-local species.

Acacia trigonophylla in the Jarrah Forest

Our observations have revealed that large numbers of *Acacia trigonophylla* individuals are planted on many road verges around Perth and along major roads in the northern Jarrah Forest. For example, hundreds of plants can be seen flowering in June and July on Albany Highway between Armadale and Gleneagle. From file searches of Main Roads archives in the Battye library it appears that *Acacia trigonophylla* was selected for this roadside mix because the species is a large obligate reseeding shrub to 2 metres tall, which sets very large amounts of easily collected seed, growing rapidly but not becoming woody and thus is a very useful roadside

Figure 4. Plants of *Acacia trigonophylla* in rehabilitation/restoration site at Anketell Road (Jandakot, Photo: Vanda Longman).

screening plant. The species was also widely planted in the early years of reafforestation after bauxite mining in the northern Jarrah forest. The species was widely used by Alcoa for pre 1988 revegetation in the early mines ay Del Park north of Jarrahdale, often collected in mistake for *Acacia alata* (Gardner and Bell, 2007, E. D. Kabay, pers.com.).

Maslin (2001) in his treatment and locality map of this species in the Flora of Australia limits the species to the IBRA regions of the Geraldton Sandplains (an old, possibly doubtful-record according to Maslin), Avon Wheatbelt and Mallee on granite and duplex soils (map 430, Maslin 2001 and in World Wide Wattle (2016)), with no records shown

from the Jarrah Forest. In the Flora of Australia treatment Australia, Maslin says *A. trigonophylla* is from Rocky Gully which is on the far eastern portion of the Jarrah Forest and is not too far from Frankland River Crossing.

However, FloraBase (Western Australian Herbarium, 1998–) has six collections of *Acacia trigonophylla* from the Jarrah Forest Bioregion in PERTH, all given as native. One collection in Melbourne [herb MEL] is from the lookout on Kingsbury road (Brown 213), while others at PERTH are from the adjacent Buddhist monastery (Nyanatusita 36) and further south on Scarp Road (Kabay 1546). In all these areas *Acacia trigonophylla* is only found along the road-verge or immediately adjacent and does not occur in the adjacent intact bushland beyond the road verge despite frequent control burns and other disturbances. We have revisited these localities and there seems little doubt that the three records from these sites are the result of plantings along roadsides and at vista points by the Main Roads Department and for revegetation by Alcoa along Scarp Road.

The other collections in PERTH are from the Frankland River Crossing on Muir Highway (west of Rocky Gully?) and two from the same site, a granite rock near Wandering may be native to the region, but we have not visited these localities. However, all appear to be road verge records and are considered doubtfully native. All records from the western and northern side side of the Jarrah forest are naturalised populations.

Figure 5 shows a map of collections of *Acacia trigonophylla* as well as locations where it has become established, and is probably naturalised, outside of its native range.

PREVENTION OF ERRONEOUS DISTRIBUTION MAPS

The authors feel that a few simple rules may lessen erroneous distribution data and these could include:

1. Try not to make general collections of native plants on disturbed road verges, gravel pits or areas where revegetation has occurred,
2. Clearly label the collection with the above data and/or a statement of condition of the bushland,
3. Databased collections need a field to indicate if the collection is planted, naturalised or dubiously native to the location before they are added to a species map
4. The resulting map should clearly indicate the status of the collection point (e.g. see our map in figure 5)

The identification of non-local native plants becomes more challenging if distribution maps include a mixture of collections and records from both natural

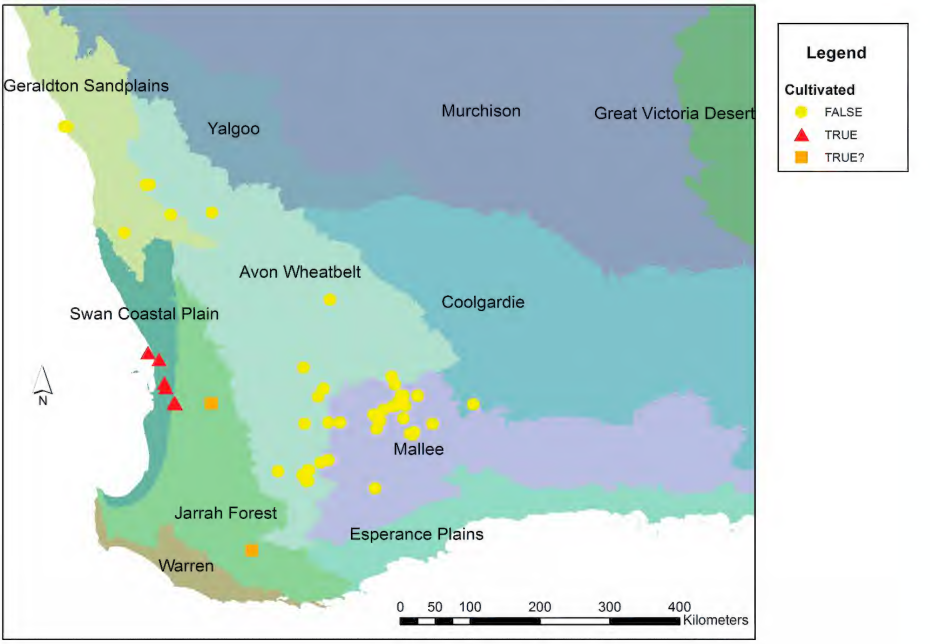

Figure 5. Map of southwestern WA showing the distribution of collections of *Acacia trigonophylla* from collections in herbaria, as well as from observations of naturalised plants discussed in the text. Only yellow dots should be given as verified localities. IBRA regions are also shown.

populations and established plants (planted and/or naturalised) from outside of the natural range of species. Clearly, collections held at Australian Herbaria that are obviously not part of the species' native range should not be allocated a latitude/longitude to avoid erroneous distribution maps. Or, if they are geocoded, the resulting map should clearly indicate that the population is cultivated or a naturalised occurrence. Failure to do this will contribute to the inclusion of non-local native plants in restoration projects and some of these may become environmental weeds.

There are also many people, consultants, researchers and interested public that use species lists from database searches for preparing lists of local native plants. Inclusion of records of species that are not indigenous to the area of the search causes unnecessary errors in the utility of these data sets.

CONCLUSIONS

Current botanical monographs and databases show that *A. trigonophylla* is considered to occur naturally in the Geraldton Sandplains, Avon–Wheatbelt and Mallee Bio-Regions. Re-

examination of all collections held at relevant Australian Herbaria has indicated that the species is probably also native to the south -eastern portion of the Jarrah Forest Bio-Region (Jarrah Forest 2 subregion), but this remains to be substantiated. Currently there is no evidence that *A. trigonophylla* is native to the Swan Coastal Plain or adjacent areas of the Jarrah Forest (Jarrah Forest1 sub-region), especially in the Perth Metropolitan Area. Additionally, there is strong evidence that the populations of *A. trigonophylla* within the Perth region were the result of planting of this species or its inclusion in seed mixes used for revegetation. Our observations show that this species has the potential to become a major environmental weed in Perth's urban bushlands and we strongly recommend that it be excluded from future revegetation projects in this region.

We have also noted a number of other native plants from other bio-regions of Western Australia that have the potential to become naturalised as environmental weeds in the Perth region. These issues would not arise if the species and provenances of plants used in revegetation projects are native to local floristic communities.

ACKNOWLEDGEMENTS

Karen Jackson located the population of *Acacia trigonophylla* in Shirley Balla Reserve, Jandakot.

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Time to maturity in the Zamia Palm *Macrozamia riedlei* – The genus *Macrozamia* (Family Zamiaceae) with 42 currently named species is confined to Australia. Most species are restricted to eastern Australia. Three species of *Macrozamia* are currently recognized in the south-west of Western Australia (WESTERN AUSTRALIAN HERBARIUM. 1998–). The most widely distributed is *Macrozamia riedlei* (Gaudich.) C.A. Gardner which is widespread on lateritic soils in the Fitzgerald, Northern Jarrah Forest, Perth, Southern Jarrah Forest and Warren IBRA Subregions. It is usually trunkless and its fronds commonly grow to about 0.5–1m high. The other two south-western species occur mainly on sandy soils. These are *M. fraseri* Miq. which occurs In the Dandaragan Plateau, Lesueur Sandplain, Northern Jarrah Forest and Perth IBRA Subregions and *M. dyeri* (F. Muell.) C.A. Gardner which is confined to the Recherche IBRA Subregion. These latter species have variable trunks, sometimes more than 2 metres tall.

Some information is available on the life history and sex-ratios of *Macrozamia*. Baird (1939) studied in detail the life history of *M. reidlei* at various locations on the Swan Coastal Plain and the Darling Range and Ornduff (1985) examined sex ratios in eight populations of *M. riedlei* between Perth and Northcliffe. Unfortunately at the time of both of these studies, the taxonomy of *Macrozamia* had not been resolved with only one species then being recognized. As these studies included both *M. riedlei* and *M. fraseri*, regional differences discussed by these authors were not distinguished from between-species differences.

Despite their relative abundance and distribution little is known about growth rates, time to maturity, and age in any of these slow growing perennial dioecious species. However, a study of 20 large *Macrozamia* by Pate (1993) from sites at Badgingarra and Dwellingup (identified as *riedlei* but possibly both *riedlei* and *fraseri* on currently understood distribution) suggested that their ages ranged between 670 and 1530 years.

Presented here are some data on age to maturity in *Macrozamia riedlei*.

In 1972–73 on a private property in Paulls Valley in the Perth Hills adjacent to what was then State Forest and now Beelu National Park an area had the surface vegetation removed whilst retaining the integrity of the soil structure. A house was built on part of this area but beyond the retention of a cleared zone of about 7 metres for fire protection the vegetation was allowed to regenerate. This comprised Marri *Corymbia calophylla* as well as a

Figure 1. A female *Macrozamia riedlei* with mature seeds photographed 1 April 2017.

Figure 2. A male *Macrozamia riedlei* with decomposing spore cone photographed 1 April 2017.

number of shrub species including *Macrozamia riedlei.*

At the end of March 2017 it was noted that a female zamia had produced a seed cone which was breaking apart and revealing the red seeds (Figure 1). A male plant (Figure 2) with at least two decomposing spore cones was a few metres away. This was the first time that either plant had produced a reproductive cone. Thus the period of time for these two specimens of *Macrozamia riedlei* to first reproduce was 44 years. Accordingly, individuals of *M. riedlei* are both slow to mature as well as long-lived.

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